

# COMMONWEALTH OF AUSTRALIA

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Family Name						
Given Names						
Student Number						
Teaching Period	Semester 2, 2015					

FINAL EXAMINATION	DURATION
ENG174 – Electrical Engineering	
	Reading Time: 10 minutes
	Writing Time: 120 minutes

### INSTRUCTIONS TO CANDIDATES

- 1.1 The exam consists of Four (4) questions.
- 1.2 Note that questions ARE NOT of equal value.
- 1.3 Read ALL questions carefully.
- 1.4 Show all diagrams, units and workings necessary to justify your answers. Insufficient working will result in a loss of marks.
- 1.5 Do not commence writing until instructed to do so.

### EXAM CONDITIONS

This is a RESTRICTED OPEN BOOK examination

Any non-programmable calculator is permitted

One A4 sheet of handwritten double-sided notes permitted

No dictionaries are permitted

Answer on the supplied examination material/s only

ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED
Lecture Textbook/s (Unannotated)	1 x 20 Page Book

**THIS EXAMINATION IS PRINTED  
DOUBLE-SIDED.**

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## Question 1 (13 Marks)

Consider the circuit shown below in figure 1

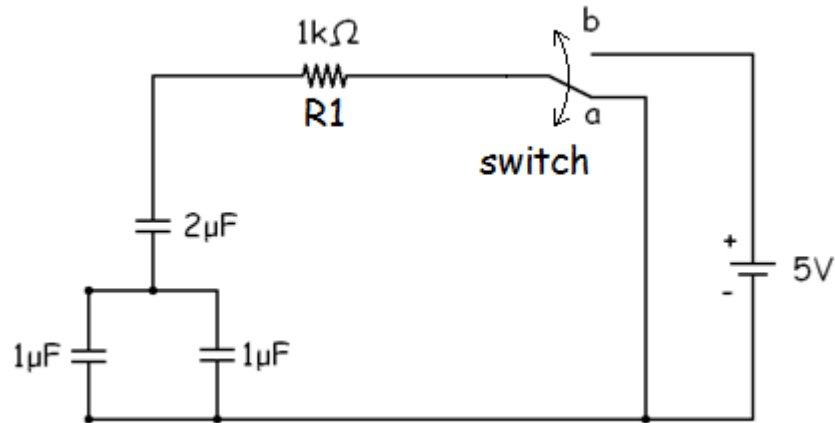


Figure 1

- a) Re-draw the circuit and simplify the 3 capacitors shown into one single capacitor and label it C1. (1 Mark)

The switch has been in position **a** for a long time. At time,  $t=0$  seconds, the switch is moved from position **a** to position **b**.

- b) Showing sufficient working and explanation, calculate the voltage across the capacitor, C1, and the current flowing through the resistor, R1 for the moment in time immediately after  $t=0$ . (Just after the switch has moved from **a** to **b**) (3 Marks)

If the switch is left in position **b** for some time and the voltage across the capacitor, C1, is observed to change over time until it eventually reaches a final voltage,  $V_{\text{final}}$  at time =  $t_{\text{final}}$ . After reaching  $V_{\text{final}}$ , the voltage across C1 no longer changes.

- c) Showing sufficient working and explanation, calculate  $V_{\text{final}}$  (2 Marks)
- d) Again, showing sufficient working and explanation, calculate  $t_{\text{final}}$  in seconds (2 Marks)
- e) How much time must elapse after moving the switch from **a** to **b** for the voltage across C1 to be equal to 80% of  $V_{\text{final}}$ ? (3 Marks)
- f) Sketch a graph of voltage across C1 verses time, from time = 0 seconds to time =  $t_{\text{final}}$ . Ensure you include all important information on your sketch. (2 Marks)

Ensure you include full explanations of any assumptions you rely on for your answers.

The following formula may prove useful:

$$y(t) = Y_{\text{Final}} + (Y_{\text{Initial}} - Y_{\text{Final}}) e^{-\frac{t}{\tau}}$$

## Question 2 (12 Marks)

In airfield lighting, it is common practice to connect large numbers of lights in a single circuit, such as the schematic show below in Figure 2. This not only reduces the amount of wire required but also ensures that all globes are the same brightness as they all have the same current flowing through them.

To overcome the risk of a single light failing and hence breaking the circuit, the lights themselves (lamp 1 to lamp n) are not connected in series, rather they are connected to the secondary side of a small transformer (T1 to Tn) and each of the primary sides of these transformers are connected in series.

The entire circuit is powered by a constant current source (AC in) through another, high power, transformer (Tmain). Only 4 lights are shown for clarity and the dotted wire indicates more globes in the circuit. The small transformers, T1 to Tn have a turns ratio of 2:1 and the current on the secondary side of Tmain, ( $I_s$ ) is kept constant at  $4 A_{RMS}$ . Assume all transformers are ideal.

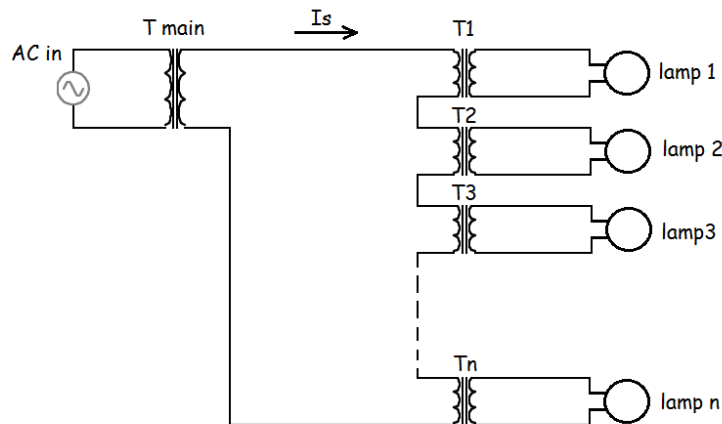


Figure 2 Airfield lighting circuit.

- If 100 lamps were to be connected in this way, what must the minimum power rating be for Tmain if each bulb has a resistance of  $6\Omega$  when on? **(3 Marks)**
- If the current on the primary side of the transformer Tmain needs to be  $96A_{RMS}$  to ensure that the secondary current ( $I_s$ ) is  $4A_{RMS}$ , what kind of transformer is Tmain and why? **(2 Marks)**
- If Tmain has 1200 turns on its secondary winding, how many turns must it have on its primary winding? **(1 Mark)**
- If twice the number of globes specified in part (a) are connected, what must be the voltage across the constant current supply, ACin? **(4 Marks)**
- If one globe was to fail (become an open circuit), what effect would this have on the voltage and current on the primary side of Tmain and why? **(2 Marks)**

Show all necessary steps for each part of your answer.

### Question 3 (13 Marks)

The equivalent circuit for a brushed DC motor is shown below in Figure 3. The torque produced by the motor at its output shaft,  $T_o$ , is proportional to the current flowing into the motor,  $I_o$ . This relationship can be expressed by the following formula:

$$T_o = kI_o \text{ where } k \text{ is the motor constant.}$$

When the motor is turning and its coils are passing through a magnetic field, a voltage,  $E_o$ , (or Back EMF) is created in the circuit. This back EMF is proportional to the speed at which the motor rotates (measured in radians per second):

$$E_o = k\omega_m \text{ where } k \text{ is again the motor constant.}$$

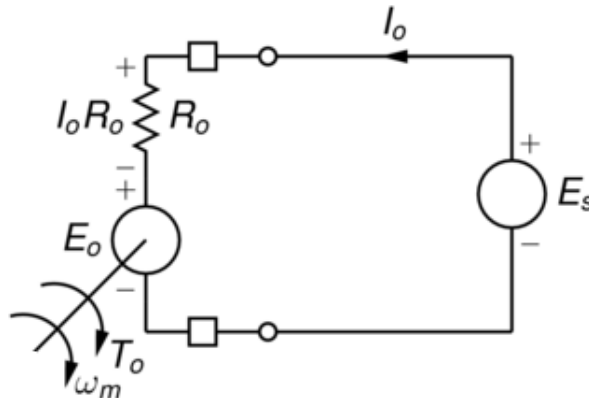


Figure 3.

- a) In order to determine the value of  $k$ , you conduct an experiment where you replace the voltage source  $E_s$  with a voltmeter and use a second powered motor to spin this motor first at a constant speed of 10 radians per second then at a constant speed of 20 radians per second. At 10 radians per second, the voltmeter reads 4 volts DC.
  - i) What voltage does the value on the voltmeter represent and why? **(2 Marks)**
  - ii) What is the value for the motor constant,  $k$ ? **(1 Mark)**
  - iii) What should the voltmeter read when the motor is spinning at a constant speed of 20 radians per second? **(1 Mark)**
- b) Having determined the value for  $k$  you remove the second motor and attach a torque sensor to the motor shaft. You then reattach the power supply,  $E_s$ , and increase the voltage of  $E_s$  until the motor is now spinning under its own power at 15 radians per second. The power supply  $E_s$  needs to be set to 10V to achieve this speed and the torque meter is reading 0.8 Newton metres. Determine the current flowing out of the power supply,  $I_o$ , and the equivalent resistance of the motor,  $R_o$ . **(3 Marks)**
- c) If you then keep the voltage supplied to the motor from  $E_s$  at 10V, and increase the load on the motor until the torque meter reads 1.2 Newton metres, what is the power being supplied by the voltage source  $E_s$  and what is the efficiency of the motor, in terms of electrical power to mechanical power, when it is run this way? **(4 Marks)**
- d) Explain, with the aid of diagrams if necessary, why the current draw from the supply is always at maximum the instant you turn on this type of motor. **(2 Marks)**

For each question, show all necessary working and state clearly any assumptions you make.

## Question 4 (12 Marks)

Two ac power supplies are connected together in series;  $v_1(t) = 100 \cos(120\pi t + 30^\circ)$  and  $v_2(t) = 250 \sin(120\pi t + 150^\circ)$ .

- a) Use phasors to find the total voltage across both supplies,  $v_{total}(t) = v_1(t) + v_2(t)$  and then express  $v_{total}(t)$  in the form  $V_m \cos(\omega t + \theta)$ . **(3 Marks)**

The impedance of the various circuit components, calculated at  $\omega = 1000$  radians per second is shown below in Figure 4:

- b) Calculate the total impedance between nodes **a** and **b**. Show all necessary steps. **(3 Marks)**
- c) A voltage,  $v_{in}(t) = 340 \cos(\omega t + 60^\circ)$  is applied to node **a** with respect to node **b**. Calculate the current flowing through the circuit element with impedance  $-j25\Omega$ . **(3 Marks)**
- d) Is this current leading or lagging the voltage, explain your answer. **(1 Mark)**
- e) The circuit element with impedance  $j20\Omega$  is an inductor. What is its inductance in henrys? **(2 Marks)**

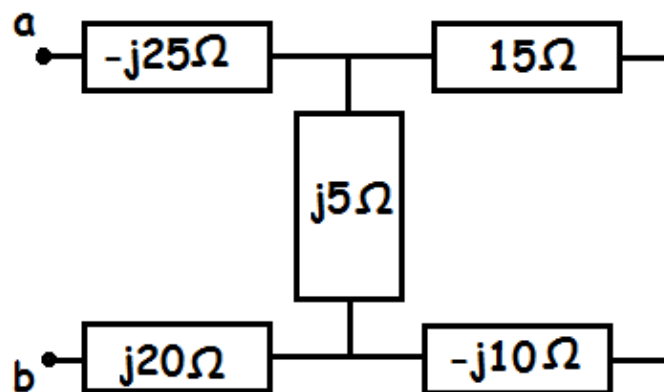


Figure 4.